packed with helices and maintained at 250°. The products were isolated in a similar manner, yielding 55% *trans*-3-methyl-1,3,5-hexatriene and 45% 2-methyl-1,3-cyclohexadiene (**8**, 74% recovery).

B.—A similar thermolysis at 350° yielded 43% *trans*-3-methyl-1,3,5-hexatriene, 1% **5**, 44% **8**, and 12% **9** (78% recovery).

C.—A similar thermolysis at 250°, except that activated alumina (8–14 mesh) was utilized instead of Pyrex helices, yielded 37% *trans*-3-methyl-1,3,5-hexatriene, 40% **8**, and 13% **9** as well as several minor products (65% recovery).

D.—A thermolysis similar to **C** at 350° yielded 20% *trans*-3-methyl-1,3,5-hexatriene, 6% **5**, 26% **8**, and 32% **9** as well as several minor products (72% recovery).

Registry No.—**5**, 19656-98-5; **8**, 1489-57-2; **9**, 1489-56-1; **10**, 1888-90-0.

The Chemistry of 10α-Estr-4-en-17β-ol-3-one and Selected Transformation Products[1]

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Hydrogenation of estra-4,9(11)-dien-17β-ol-3-one (**1**) gave 10α-estr-4-en-17β-ol-3-one (**2**), the parent member of a new series of steroids. Spectral studies indicate that ring B in this series has a boat conformation. This strained system is readily isomerized to 19-nortestosterone in acids and in base. Reduction with lithium aluminum tri-*t*-butoxyhydride gave the corresponding equatorial 3α-alcohol **7**, which was converted into the 3-deoxy-Δ^4 and -$\Delta^{5(6)}$ olefinic analogs by hydrogenolysis with lithium in ethylamine. The C-4 double bond appears to shift to the corresponding C-5(6) olefin in the presence of strong base. Reduction of **2** with lithium–ammonia solutions gave 10α,5β-estra-17β-ol-3-one (**10**).

Alteration of one or more of the asymmetric centers in the steroid nucleus has led to some interesting changes in its chemical and biological properties.[2] In the present study we would like to describe the synthesis and chemistry of 10α-estr-4-en-17β-ol-3-one (**2**) and of some of its derivatives.

The introduction of the 10α stereochemistry in the estrene nucleus was readily accomplished by selective catalytic hydrogenation of the 9(10) double bond of estra-4,9(10)-dien-17β-ol-3-one (**1**),[3] using as catalyst either palladium on barium sulfate or 2% palladium on strontium carbonate in benzene.[4] The latter resulted in a high degree of selectivity, giving directly in 60% yield a dihydro product which was identified as 10α-estr-4-en-17β-ol-3-one (**2**). In general, all other catalysts and reaction conditions studied gave significant quantities of mixed tetrahydro and aromatized steroids.

Spectral properties of **2** displayed features characteristic of a 19-nortestosterone derivative.[5] Inspection of ORD and CD spectra using dioxane as solvent showed a small negative Cotton effect in the π–π^* region, a result similar to that reported for 10α-testosterone.[6,7] Surprisingly, a small positive Cotton effect was obtained in this region with methanol.[8] The sign of the Cotton effect in the n–π^* region is negative in both solvents. This change in sign in the low-wavelength region can be attributed to a solvation effect. Alternately, and perhaps more likely, a shift in the conformer populations may occur upon changing polarity. Neither 19-nortestosterone nor its 9β,10α-isomer exhibit this behavior. Examination of Dreiding models of **2** revealed that the A ring is relatively flat and can readily assume a positive or a negative chirality. The RD results obtained in dioxane, when analyzed using the chirality rule,[7] are best accommodated by assignment of 10α stereochemistry to the dihydro product **2**. The most plausible conformation consistent with these data is shown in Figure 1. The nmr spectrum of **2** reflects a greater degree of shielding of the C-18 methyl groups by its greater proximity to the C–C bonds in rings A and B resulting in a net diamagnetic shielding, relative to its 10β isomer **5**.[9] The chemical shifts of the C-18 methyl groups of several of the 10α-estrenes reported in this study are shown in Table I, together with those of some corresponding 10β analogs.

The steric strain resulting from the ring-B boat conformation can be readily relieved by enolization and reprotonation at C-10β to give 19-nortestosterone (**5**) after acid or base treatment.[10,11] The configuration of the C-9 proton was therefore confirmed by the isolation of **5** and confirmed further by the hydrogenation of **2** to give the known 10α ketone **6**.[2g,h]

The monoacetate **3**, which could also be obtained by hydrogenation of the diene acetate **4**, was reduced with

(1) For a preliminary report regarding part of the present work see E. Farkas, J. M. Owen, M. Debono, R. M. Molloy, and M. M. Marsh, *Tetrahedron Letters*, 1023 (1966).

(2) For some recent examples of syntheses of steroids bearing unnatural stereochemistry at one or more asymmetric centers, see (a) P. Westerhof and E. H. Reerink, *Rec. Trav. Chim. Pays-Bas*, **79**, 771 (1960); (b) R. Wenger, H. Dutler, H. Wehrli, K. Schaffner, and O. Jeger, *Helv. Chim. Acta*, **45**, 2420 (1962), and **46**, 1096 (1963); (c) L. Velluz, G. Nominé; R. Bucourt, A. Pierdet, and J. Tessier, *Compt. Rend.*, **252**, 3903 (1961); (d) J. A. Edwards, P. Crabbé, and A. Bowers, *J. Amer. Chem. Soc.*, **85**, 3313 (1963); (e) P. Westerhof, *Rec. Trav. Chim. Pays-Bas*, **83**, 1069 (1964); (f) F. Sondheimer, R. Mechoulam, and M. Sprecher, *Tetrahedron*, **20**, 2473 (1964); (g) R. T. Rapala and E. Farkas, *J. Org. Chem.*, **23**, 1404 (1958); (h) R. E. Counsell, *Tetrahedron*, **15**, 202 (1961).

(3) M. Perelman, E. Farkas, E. J. Fornefeld, R. J. Kraay, and R. T. Rapala, *J. Amer. Chem. Soc.*, **82**, 2402 (1960).

(4) R. B. Woodward, F. Sondheimer, D. Taub, K. Heusler, and W. M. McLamore, *ibid.*, **74**, 4223 (1952).

(5) (a) A. J. Birch, *J. Chem. Soc.*, 367 (1950); (b) A. L. Wilds and N. A. Nelson, *J. Amer. Chem. Soc.*, **75**, 5366 (1953).

(6) See ref 2b.

(7) W. Moffit, R. B. Woodward, A. Moscowitz, W. Klyne, and C. Djerassi, *J. Amer. Chem. Soc.*, **83**, 4013 (1961).

(8) A. Moscowitz, K. M. Wellman, and C. Djerassi, *Proc. Natl. Acad. Sci. U. S.*, **50**, 799 (1963).

(9) Shielding of hydrogen nuclei in rigid systems is believed to be due to diamagnetic anisotropic contributions associated with neighboring C–C bonds; see L. M. Jackman and R. H. Wiley, *J. Chem. Soc.*, 2881 (1960). For other leading references see J. W. Emsley, J. Feeney, and L. H. Sutcliffe, "High Resolution Nuclear Magnetic Resonance Spectroscopy," Vol. II, Permagon Press, New York, N. Y., 1966.

(10) This transformation has precedence in the base-catalyzed epimerization of the C-6 methyl group in the 6β-methyl-Δ^4-3-one system; see ref 11.

(11) A. Bowers and H. J. Ringold, *J. Amer. Chem. Soc.*, **80**, 3091 (1958); H. J. Ringold, E. Batres, and G. Rosenkranz, *J. Org. Chem.*, **22**, 99 (1957).

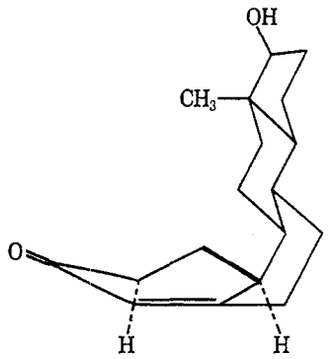


Figure 1.—Schematic representation of the conformation of 2.

TABLE I

Nmr Data for Some 19-Nor Steroids

Steroid	Chemical shift, ppm[a] C-18	C-4	C-6
1	0.90	5.67	
2	0.70	5.90	
3	0.77	5.87	
5	0.83	5.88	
10	0.80	5.38	
11	0.70	5.39	
11 (Δ^5 isomer)	0.75		5.65[b]
12	0.83	5.42	
13	0.84		5.68[b]
13 (Δ^4 isomer)	0.83	5.40	
10β-Estr-4-en-17β-ol	0.78	5.40	
10β-Estr-4-en-17-one	0.89	5.44	
10β-Estr-4-en-17α-ethynyl-17β-ol	0.87	5.43	
10β-Estr-5(6)-ene-3α,17β-diol diacetate	0.80		5.55[b]

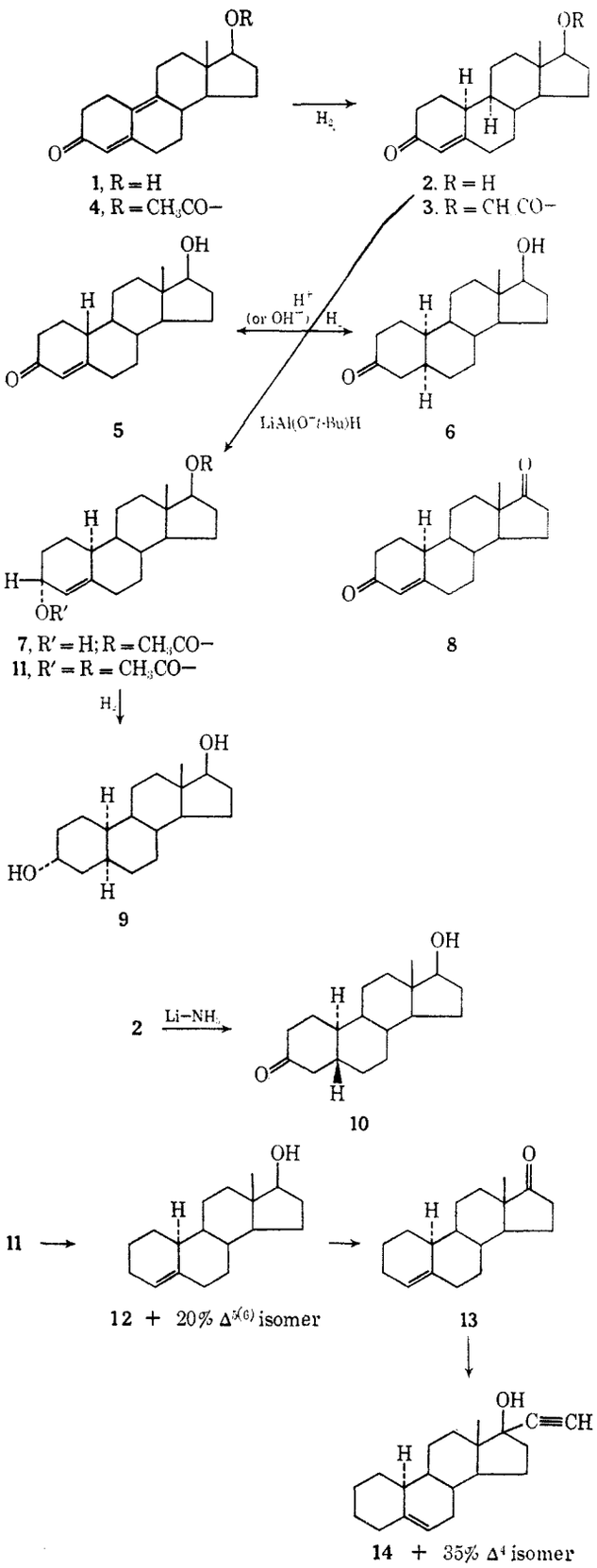
[a] Data for solution in $CDCl_3$. [b] The $\Delta^{5,6}$ olefins reported here exhibited allylic coupling of 3–6 Hz. No such coupling was observed for the corresponding Δ^4 isomer.

lithium tri-*t*-butoxyaluminum hydride to give the corresponding C-3 alcohol **7** in high yield[1] (Scheme I). Oxidation of **7** with activated manganese dioxide readily gave back **3** to confirm that the reduction and oxidation did not alter the 10α stereochemistry. Furthermore, **2** was found to undergo Sarett oxidation to the 3,17-dione **8** without altering the C-10 configuration.[12]

Wheeler and Mateos[13] reported that lithium tri-*t*-butoxyaluminum hydride reduced cholest-4-en-3-one quantitatively to the equatorial 3β-alcohol. Similarly, the reduction of **3**, which exists in a rigid conformation (see Figure 1), leads to the alcohol **7** whose C-3 hydroxyl group is both 3α and equatorial.[14] This assignment was confirmed by the conversion of **7** to 5α,10α-estra-3α,17β-diol (**9**) by hydrogenation and subsequent hydrolysis. The isolation of **7** verifies the plausibility of the conformation deduced from the ORD–CD data.

Chemical reduction of **2**, using a solution of lithium in liquid ammonia, resulted in the isolation of 5β,10α-estran-17β-ol-3-one (**10**) (60%) as the major product.[1,9] The fact that this material was different from the known

SCHEME I



10β,5α-[15] and the 10β,5β-estran-17β-ol-3-one[16] suggests that no epimerization at C-10 occurred before or during reduction. The 5β stereochemistry of the product is

(12) G. I. Poos, G. E. Arth, R. E. Beyler, and L. H. Sarett, *J. Amer. Chem. Soc.*, **75**, 422 (1953).

(13) (a) O. R. Vail and D. M. S. Wheeler, *J. Org. Chem.*, **27**, 3803 (1962); (b) O. H. Wheeler and J. L. Mateos, *Chem. Ind.* (London), 395 (1957).

(14) S. G. Levine, N. H. Eudy, and E. C. Farthing, *Tetrahedron Letters*, 1517 (1963).

(15) A. Bowers, H. J. Ringold, and E. Denot, *J. Amer. Chem. Soc.*, **80**, 6115 (1958), and references cited therein.

(16) R. T. Rapala and E. Farkas, *ibid.*, **80**, 1008 (1958).

consistent with the current theory of metal–ammonia reduction indicating β protonation of the stereoelectronically favored transition state (ring B half-chair).[17] The strong negative Cotton effect for **10** in the RD spectrum was communicated previously.[1] Additional support for this stereochemistry can be obtained from the nmr spectrum where the C-18 methyl protons of **10** occur at 42 cps, while the corresponding signal for the all-*trans* 5α,10β-estran-17β-ol-3-one occurs at 47 cps.

Hydrogenolysis of the allylic diacetate **11** with a solution of lithium in anhydrous ethylamine resulted in the isolation of a mixture of olefins (**12**).[18] The nmr spectrum of this mixture showed two distinct signals for olefinic protons at δ 5.42 and 5.65 ppm in a 3:2 ratio. In an analogous reaction sequence using the 10β isomer, only a single olefin, 10β-estr-4-en-17β-ol, was obtained; it showed a single nmr signal at δ 5.46 ppm.[19] Oxidation of mixture **12**, followed by careful purification, resulted in the isolation of one of the olefinic components as the 17-ketone **13**. Its nmr spectrum showed a single olefinic signal at δ 5.42 ppm, verifying that this signal was due to a single trisubstituted olefinic proton. The second component with the higher field nmr signal for its olefinic proton could not be purified.

In a variety of steroids the $\Delta^{5(6)}$ olefinic proton has a higher chemical shift than that of the corresponding Δ^4 isomer.[20] The δ 5.65 ppm signal shown by **12**, therefore, is assigned to the $\Delta^{5(6)}$ isomer, while the lower field signal at δ 5.42 ppm is attributed to the Δ^4 olefin. The chemical shifts of the angular methyl groups in **12** and **13**, when compared with similar compounds in the 10β series, are consistent with the assignment of the 10α-estrene structure to these compounds. Ethynylation of **13** to **14** with lithium acetylide–ethylenediamine complex[21] caused a reappearance of the mixture of olefinic isomers (nmr signals at δ 5.46 and 5.65 ppm). In this case the $\Delta^{5(6)}$ isomer predominated (65%) as estimated by integration of these nmr signals. The longer reaction time for ethynylation (6 hr) seems to favor the $\Delta^{5(6)}$ isomer, as compared to the lithium–ethylamine hydrogenolysis reaction which results in the formation of more of the Δ^4 olefins. The longer time could be expected to increase the thermodynamically favored product.

Careful purification of the ethynylation product gave nearly pure $\Delta^{5(6)}$ olefin (**14**). Its nmr spectrum showed the presence of a single trisubstituted olefinic proton at δ 5.62 ppm. These results demonstrate that in the 10α series the Δ^4 olefin can be converted to the $\Delta^{5(6)}$ isomer by organometallic bases.[22] No such transformation of Δ^4 to the $\Delta^{5(6)}$ olefin is observed in the 10β case, indicating that this conversion is probably a function of stereochemical differences. These differences are probably related to the steric strain inherent in the 10α-estrene system resulting from the ring-B boat conformation. This steric strain can be reduced by a shift of the Δ^4 olefinic bond to the $\Delta^{5(6)}$ position, thereby converting ring B to a half-chair conformation which is more planar and less strained.[23] The mechanism of this shift can be rationalized by postulating the formation of an allylic carbanion which can result from abstraction of a C-6 proton by an organometallic base. The double bond can then shift to the more sterically favored $\Delta^{5(6)}$ position, contributing considerably to relief of steric strain which is the probable driving force for this transformation.[18]

Experimental Section[24]

Estra-4,9(10)-dien-17β-ol-3-one (1).—A solution of 10 g (0.037 mole) of estr-5(10)-en-17β-ol-3-one[3] in 288 ml of dry pyridine was cooled to 0°, and 11.5 g (0.036 mole) of pyridinium bromide perbromide was added in portions with vigorous stirring. The temperature was maintained at 0° for an additional 1 hr and at room temperature for 3 hr. The brown reaction mixture was poured into 700 ml of saturated NaCl solution, extracted with CH_2Cl_2 (three times), washed with 5% HCl (eight times) and then with saturated NaCl, and dried (Na_2SO_4). Evaporation of the solvent under vacuum gave a tan crystalline product which was recrystallized three times from acetone to give 7.23 g (72%) of 1, mp 182–184°, uv max (EtOH) 304 mμ (ε 20,400). *Anal.* Calcd for $C_{18}H_{24}O_2$: C, 79.37; H, 8.88. Found: C, 79.28; H, 9.01.

10α-Estr-4-en-17β-ol-3-one (2).—A solution of 1 (5.0 g) was hydrogenated in 318 ml of benzene containing 1.5 g of 2% Pd–$SrCO_3$ at atmospheric pressure.[4] The theoretical amount of H_2 (525 ml) was absorbed in 3 hr. Removal of the catalyst and evaporation of the solvent gave 2.13 g of fine needles (Et_2O): mp 163–165°; CD (*c* 0.00025, dioxane), $\Delta\epsilon_{380}$ ±0, $\Delta\epsilon_{361}$ −1.78, $\Delta\epsilon_{343}$ −3.46, $\Delta\epsilon_{332}$ −3.46, $\Delta\epsilon_{321}$ −2.3, $\Delta\epsilon_{310}$ −1.1, $\Delta\epsilon_{280}$ ±0, $\Delta\epsilon_{258}$ +0.25, $\Delta\epsilon_{252}$ ±0, $\Delta\epsilon_{242}$ −0.60; CD (*c* 0.00042, MeOH), $\Delta\epsilon_{375}$ ±0, $\Delta\epsilon_{323}$ −2.29, $\Delta\epsilon_{278}$ ±0, $\Delta\epsilon_{245}$ +1.8; uv max (EtOH) 243 mμ (ε 15,350); nmr ($CDCl_3$) δ 0.70 (s, 3 H, 18-Me), 5.90 ppm (s, 1 H, C-4, olefinic); ir ($CHCl_3$) 1680 cm^{-1}. *Anal.* Calcd for $C_{18}H_{26}O_2$: C, 78.79; H, 9.55. Found: C, 78.97; H, 9.33.

A solution of **2** (0.4 g) in pyridine (4 ml) and Ac_2O (2 ml) was allowed to stand overnight at room temperature. A crystalline acetate, **3**, was obtained upon removal of solvent and recrystallization from ether–petroleum ether (30–60°), mp 143–144°. This was identical with the acetate obtained by hydrogenation of the acetate of **1**.

Estr-4,9(10)-dien-17β-ol-3-one 17-Acetate (4).—A solution of 5.0 g of **1** was dissolved in 20 ml of pyridine containing 10 ml of Ac_2O. After standing at room temperature overnight, solvents were removed and residual oil crystallized from ether–petroleum ether, giving 5.83 g (94%) of **4**: mp 107.5–108°; uv max (EtOH) 303 mμ (ε 20,500); $[\alpha]^{25}D$ −290.2° (*c* 1, $CHCl_3$). *Anal.* Calcd for $C_{20}H_{26}O_3$: C, 76.40; H, 8.24. Found: C, 76.15; H, 8.47.

10α-Estr-4-en-17β-ol-3-one 17-Acetate (3).—A solution of 2.0 g (0.0063 mole) of **1** was dissolved in thiophene-free C_6H_6 (80 ml) and hydrogenated at atmospheric pressure (24°) using 0.235 g of prereduced 2% Pd–$SrCO_3$ catalyst. After 1.2 equiv of hydrogen were taken up (1.75 hr), the reaction was stopped. The catalyst was removed by filtration, and the solvent was evaporated under reduced pressure. Uv spectrum of this crude product had uv max (EtOH) 242 mμ (ε 10,350). Crystallization from 4:1 petroleum ether–ethyl ether gave 0.728 g of a crystalline solid, mp 143–144°, uv max (EtOH) 242 mμ (ε 15,200), $[\alpha]^{25}D$ − 211.3° (*c* 1.05, $CHCl_3$). *Anal.* Calcd for $C_{20}H_{28}O_3$: C, 75.91; H, 8.92. Found: C, 75.71; H, 8.85.

(17) (a) G. Stork and S. D. Darling, *J. Amer. Chem. Soc.*, **86**, 1761 (1964); (b) M. J. T. Robinson, *Tetrahedron*, **21**, 2475 (1965).

(18) A. S. Hallsworth, H. B. Hensbest, and T. I. Wrigley, *J. Chem. Soc.*, 1969 (1957).

(19) M. S. de Winter, C. M. Siegmann, and S. A. Szpilfogel, *Chem. Ind.* (London), 905 (1959).

(20) N. S. Bhacca and D. H. Williams, "Applications of NMR Spectroscopy in Organic Chemistry," Holden-Day, Inc., San Francisco, Calif., 1964, p 88.

(21) O. F. Beumel, Jr., and R. F. Harris, *J. Org. Chem.*, **29**, 1872 (1964).

(22) The nmr signals of $\Delta^{5(6)}$olefinic protons in the 10β-estrene and the androstene series were observed to possess a 3–4-Hz allylic coupling which was not so pronounced in the corresponding signal for the Δ^4 isomer.

(23) The $\Delta^{5(6)}$ isomers in **8**, **9**, and **10** have angular methyl signals 2–3 Hz upfield from those of the Δ^4 isomer which qualitatively confirms that the $\Delta^{5(6)}$ double bond serves to flatten out the nucleus in the 10α series (see ref 9).

(24) Melting points are uncorrected. Uv spectra were recorded on a Cary 15 spectrophotometer. Ir spectra were determined on a Perkin-Elmer 21 instrument in $CHCl_3$. Nmr spectra were obtained on a Varian HR-60 with TMS as internal standard. The CD and ORD curves were recorded on a Cary 50 recording spectropolarimeter.

Epimerization of 2 to 19-Nortestosterone. A. Basic Conditions.—A solution of 0.1 g of **2** in 10 ml of MeOH was treated with 0.85 ml of a sodium methoxide solution (0.1 g of sodium/10 ml of MeOH) under nitrogen atmosphere and refluxed overnight. Most of the solvent was removed under vacuum, and excess water was added. The reaction mixture was extracted several times with ether, washed with 10% $NaHCO_3$ and NaCl solutions, and dried ($MgSO_4$). The residue, after removal of solvent, was chromatographed on 10 g of Florisil using Et_2O. Fractions 3–6 (55-ml fractions) were combined and crystallized from ether to give 0.045 g of a crystalline compound, mp 110–112°, which gave no depression on admixture with authentic 19-nortestosterone.[5]

B. Acidic Conditions.—To a solution of 0.03 g of **2** in 5 ml of $CHCl_3$ was added 1 ml of a saturated solution of HCl gas in $CHCl_3$. After refluxing overnight, the solution was poured into excess water and extracted with CH_2Cl_2. The organic layer was washed with 10% $NaHCO_3$ solution and NaCl solution successively, and then dried ($MgSO_4$). Evaporation of the solvent under vacuum gave 0.008 g of an oil which was crystallized from Et_2O. The properties of this material were identical with those of 19-nortestosterone.[5]

Hydrogenation of 2 to 5α,10α-Estran-17β-ol-3-one (6).—A solution of 0.082 g of **2** in EtOH (30 ml) was hydrogenated at atmospheric pressure, using 0.082 g of 5% Pd–$BaSO_4$. One equivalent of hydrogen was taken up in 30 min, the catalyst was filtered off, and the solvent was removed under vacuum. The residue crystallized from Me_2CO–Skelly B to give 0.11 g of **5**, mp 150–151°, whose X-ray pattern was identical with that of authentic 5α,10α-estran-17β-ol-3-one.[2g,h]

10α-Estr-4-ene-3,17-dione (8).—To a cold mixture of pyridine (3 ml) and chromic anhydride (0.4 g) was added a cold solution of 0.4 g of **7** in 5 ml of pyridine.[12] This mixture was kept at ice-bath temperatures for 15 min and allowed to warm to room temperature overnight. The dark mixture was diluted with water and extracted thoroughly several times with ether. The combined ether extract was washed with 5% HCl and then with saturated NaCl solutions. Evaporation of solvent gave a residue which was crystallized from Et_2O, and then from Et_2O–Skelly F to give 0.29 g of **8**, mp 162–164°. *Anal.* Calcd for $C_{18}H_{24}O_2$: C, 79.37; H, 8.88. Found: C, 79.06; H, 8.88.

10α-Estr-4-ene-3α,17β-diol 17-Acetate (7).—A solution of 0.50 g (0.0016 mole) of **3** in 22 ml of freshly distilled THF was added slowly to a solution of 0.60 g (0.0023 mole) of lithium tri-*t*-butoxyaluminum hydride in 20 ml of THF and refluxed for 2 hr.[13] The reaction mixture was cooled, poured into water (30 ml), and extracted with six 200-ml portions of CH_2Cl_2. After drying ($MgSO_4$) the organic layer was evaporated to dryness under reduced pressure to give 0.479 g of white solid which crystallized from Me_2CO to give 0.30 g of **7**: mp 151.5–153°, $[\alpha]^{25}D$ − 136.5° (*c* 1.05, $CHCl_3$). *Anal.* Calcd for $C_{20}H_{30}O_3$: C, 75.44; H, 9.49. Found: C, 75.47; H, 9.58.

5α,10α-Estrane-3α,17β-diol (9).—A solution of 0.1 g of **7** in 15 ml of EtOH containing 0.042 g of 5% Pd–C was hydrogenated at atmospheric pressure until 1 equiv of hydrogen was absorbed. The catalyst was removed by filtration, and the solvent evaporated under reduced pressure. The residue crystallized from Et_2O–Skelly F with a yield of 0.055 g of the acetate, mp 122–124°; this was dissolved in 5 ml of MeOH containing 0.04 g of powdered KOH and refluxed for 1 hr. Most of the solvent was removed and excess water was added; this was extracted thoroughly with CH_2Cl_2. The combined extract was washed with NaCl, dried ($MgSO_4$), and evaporated to dryness. The residue crystallized from Me_2CO–Skelly B to give white needles, mp 222–224° (lit.[22] mp 223–225°), and was identical with an authentic sample by mixture melting point.

5β,10α-Estran-17β-ol-3-one (10).—A solution of 1.0 g of **2** in 120 ml of dry THF was reduced according to the procedure outlined by Bowers using lithium metal (2.0 g) dissolved in liquid NH_3 (500 ml) with vigorous stirring.[15] After 20 min solid NH_4Cl was added to destroy the excess reagent, and the excess NH_3 allowed to evaporate. The residue was treated with excess water and extracted with Et_2O. Combined ether extracts were washed with NaCl solution, dried ($MgSO_4$), and evaporated to dryness.

The residue was dissolved in 3:1 C_6H_6–Skelly F and chromatographed on 100 g of grade III alumina. The reaction eluted with C_6H_6 showed only one spot on tlc and was crystallized from ethyl ether to give 0.31 g of **9** as colorless needles: mp 138–139°; ORD (*c* 0.00032, dioxane), $[\phi]_{275}$ + 1190°, $[\phi]_{298}$ ± 0, $[\phi]_{319}$ − 3487°. *Anal.* Calcd for $C_{18}H_{28}O_2$: C, 78.21; H, 10.21. Found: C, 78.09; H, 10.07.

10α-Estr-4-ene-3α,17β-diol Diacetate (11).—A solution of 0.15 g (0.45 mmole) of **7** in 1.2 ml of pyridine containing 0.6 ml of Ac_2O was allowed to stand at room temperature for 16 hr. After evaporation to dryness a yellow oil was obtained which was crystallized from petroleum ether to give 0.148 g (91%) of **11**, mp 98.5–100.5°, $[\alpha]D$ − 89.78° (*c* 1.04, $CHCl_3$). *Anal.* Calcd for $C_{22}H_{32}O_4$: C, 73.30; H, 8.94. Found: C, 73.26; H, 8.94.

10α-Estr-4-en-17β-ol (12).—A blue solution of lithium metal (11.5 g) in anhydrous $EtNH_2$ (60 ml) was carefully prepared.[18] A solution of 1.6 g of **11** in $EtNH_2$ (10 ml) was added at a rapid rate. After 10 min the reaction was quenched with careful addition of solid NH_4Cl until the blue color disappeared. The reaction mixture was concentrated to one-third volume, diluted with water, and extracted with four portions (100 ml) of CH_2Cl_2. The dried ($MgSO_4$) extract evaporated to dryness, and the resulting oil was chromatographed on 2.5 g of Florisil with 1:1 C_6H_6–petroleum ether to obtain 0.672 g of white platelets: mp 100–105° (petroluem ether); nmr, see Table I; $[\alpha]^{25}D$ − 96.14° (*c* 1.01, $CHCl_3$). *Anal.* Calcd for $C_{18}H_{28}O$: C, 83.02; H, 10.84. Found: C, 83.04; H, 10.97.

Further elution of the column gave mixtures of more polar materials which were not further investigated.

10α-Estr-4-en-17-one (13).—A solution of 0.21 g of **12** was oxidized by the Sarrett procedure using 0.21 g of CrO_3 (anhydrous).[12] The usual work-up gave an oil which eventually crystallized. This crude product was fractionally crystallized at Dry Ice–Me_2CO temperature from petroleum ether: mp 109–110.5°; nmr, see Table I; ir ($CHCl_3$) 1750 cm^{-1}. *Anal.* Calcd for $C_{18}H_{26}O$: C, 83.66; H, 10.14. Found: C, 83.56; H, 10.17.

Chromatography of mother liquors over 9.0 g of Florisil with C_6H_6–petroleum ether mixtures gave an additional 36 mg of material melting at 109–111°. Total yield was 74 mg (38.5%).

10α-Estr-5-en-17α-ethynyl-17β-ol (14).—A solution of 620 mg of **13** in THF (7 ml) was added to a stirred suspension of 368 mg of lithium acetylide (ethylenediamine complex) and 20 ml of THF at 10° while acetylene was bubbled into the reaction mixture.[21] After addition was complete, the cooling bath was removed, and the reaction was allowed to continue for 6 hr. The reaction was quenched by dropwise and cautious addition of 10 ml of concentrated NH_4Cl solution. The reaction mixture was extracted three times with CH_2Cl_2 (300 ml), and the extract was washed with water and dried ($NaSO_4$) overnight. Concentration of these extracts gave an oil (525 mg) which was chromatographed over Florisil (5.0 g). Pentane eluted 426 mg of an oil which was purified with great difficulty and which had a tendency to be hygroscopic and air sensitive when crystallized several times (71.5 mg); mp 141–142° (ether); nmr ($CDCl_3$) δ 5.69 [m, 0.8 H, C-5(6) olefin], 5.39 (m, 0.2 H, C-4(5) olefin]. *Anal.* Calcd for $C_{20}H_{28}O \cdot 0.33H_2O$: C, 82.83; H, 10.08. Found: C, 83.00; H, 10.21.

Registry No.—**1**, 6218-29-7; **2**, 5670-56-4; **3**, 6017-86-3; **4**, 19684-98-1; **7**, 19685-01-9; **8**, 5696-23-1; **10**, 19685-03-1; **11**, 19685-04-2; **12**, 19685-05-3; **13**, 19685-06-4; **14**, 19685-07-5.

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